METHODS FOR VERIFICATION OF PARAMETERS OF MAGNETIC FIELD SENSORS

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Abstract: Many new sensors appear at the market and occasionally it is required to test specification given by producer. Usually are given conditions of measurement, but the procedure stays undercover. The aim of this article is to suggest and describe simple and repeatable method for testing of magnetic field sensors and verify parameters of selected sensor.

Keywords: MEMS, sensor, verification, method

1. INTRODUCTION

Sensors of magnetic field occur almost 200 years. During this time were developed sensors operating on many different principles [1]. In last decades were production techniques improved, present technologies develop sensors in MEMS structures and the sensors are compact. The smaller size also brings worsening of some parameters, like noise characteristic or thermal stability. Producers try to keep the best parameters despite the smaller size to achieve the competitiveness with traditional ones. The biggest advantage of MEMS sensors is their price and size.

Sometimes the parameters declared by producers could be doubt, because some of them can be hardly achieved and they seem surprisingly good. The producers give the conditions of measurement, but they do not explain the procedure, which is also important. Therefore, one MEMS magnetic field sensor was chosen and were considered and described methods for their specification with available equipment. Then they can be reused with other sensors for repeated verification of parameters.

2. DESCRIPTION OF USED SENSOR

A fluxgate magnetic field sensor DRV425 [2] made by Texas Instruments was chosen as an up-to-date MEMS sensor with sufficient parameters for many applications. Range of the sensor is ±2 mT, thus it is determined to measure magnetic induction mainly bigger than is magnetic field of the Earth. Producer declares offset typically 2 µT, maximally 8 µT, error of gain 0.04 %, linearity 0.1 % and also good noise characteristics. This are the key parameters of the sensor to be verified.

For experiments was used an evaluation module for this sensor, where is provided supply for the chip, pull-up and pull-down resistors for setting of some properties and a resistor providing a conversion from electric current to voltage, which is easier measurable. Because the output is analog, for measurement must be used an additional AD converter.

Magnetic induction is calculated from the voltage by equation given by producer

$$B = \frac{V_{OUT} - V_{REF}}{48{,}8 \cdot R_1} = \frac{V_{OUT} - \frac{V_{DD}}{2}}{48{,}8 \cdot 100} \qquad [\mathrm{T; V, V}] \qquad (1)$$

Where V_{OUT} is output Voltage, V_{DD} is supply voltage and R_1 is shunt converting current to voltage. With the 100 Ω resistor built-in evaluation module is the sensor capable for measurements in range ±500 µT.

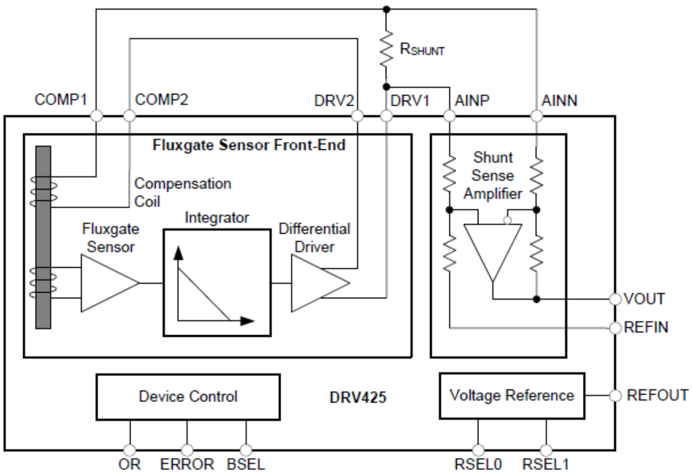

Figure 1: Functional Block Diagram of TI DRV425 [2]

3. MEASUREMENT

Before measurement of the key parameters of sensor is proper to discover test the device and measurement surrounding to avoid mistakes during the measurement. Mainly was examined impact of close metallic objects. Sensor is capable to sense a metallic object up to 50 cm. It is recommended to place no magnetic object in this area, otherwise the measurement can be influenced. An offset can be compensated by orienting the sensor at the right angle to magnetic needle. It is also important to choose suitable measuring equipment. For measurement was used simple 12-bit multimeter with resolution 1 mV at range 4 V, which stands for resolution 0.2 µT.

3.1. GAIN AND LINEARITY

For experiment verifying gain and linearity was used a Helmholtz coil [3]. It consists of two identical coils placed symmetrically in distance equal their radius and a homogenous magnetic field is formed between them. With knowledge the relation between current and created magnetic induction (constant of Helmholtz coil in units T/A) can be measured characteristics of the sensor by setting different values of electric current in the coil.

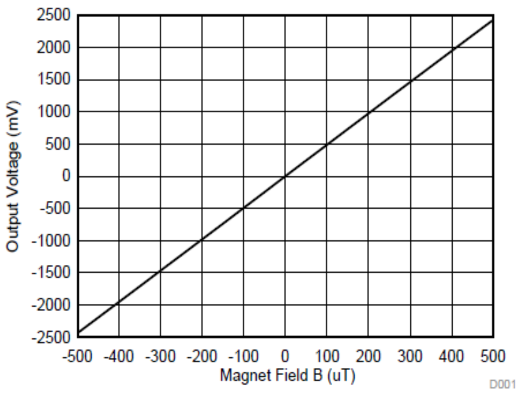

Figure 2: Output Voltage vs. Measured Field Strength given by producer [2]

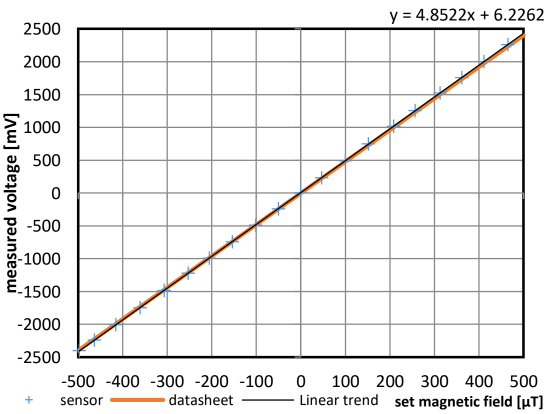

Figure 3: Measured sensitivity characteristics

The measured characteristics was broadly identical with the declared, error of sensitivity was determined as -0.6 %. In the datasheet for sensor is quantified as ±0.04 %, but this value is related just to the sensor with current output and it cannot be achieved in this configuration. The accuracy of shunt resistor is 1 %, therefore -0.6 % is a good result.

The error of linearity was determined as 0.08 %, which corresponds with datasheet value 0.1 %.

3.2. OFFSET

Offset is harder to determine in comparison with some other sensors. For example, for flowmeter is offset determined by zero stream of the fluid or for voltmeter is the input disconnected. But with magnetic field is the situation different, because magnetic field of the Earth is present and for used sensor can represent 10 % of its range. The offset is commonly determined by Zero Gauss Chamber, which reduces the surrounding magnetic field near to zero. Unfortunately, available zero chamber was too small for the sensor and PCB, so a method must had been considered, which will bring the effect of decreasing surrounding magnetic field.

Because magnetic field is a vector, it means, in a perpendicular direction is the magnitude equal zero. The orientation of the magnetic field must be found, easily by the compass, and then is necessary to place the sensor at the same place instead of the compass in the perpendicular direction.

Also was used another, similar, method based on rotation of the sensor. Firstly, the sensor was oriented to direction, where it detected the highest magnetic field. Then was turned to direction, where it detected again the highest magnetic field, but opposite direction. From these two values was calculated the arithmetic mean, which is equal to the offset. Manipulation is easier, when the sensor is fixed to some bigger pad.

Both methods showed similar results. From several measurements at different places was determined the average offset as 2.6 µT, highest was 3.8 µT. Compared to datasheet values typical 2 µT and maximally 8 µT were these values successfully confirmed.

3.3. NOISE

Noise is another important parameter, especially at measuring of low intensities of the magnetic field. Offset is not an obstacle at noise measuring, if is unchanging. It represents an DC compound at 0 Hz frequency, which wan be filtered. For fulfilment the condition of unchanging field is important to place the sensor (especially the axis of measurement) far off components causing changes of magnetic field, such as transformers, computer or power supply grid. Also is good to reduce some vibrations, which can in combination with static filed cause changes of magnetic field. Therefore, the sensor was attached to a pad.

Producer declares vibration in range up to 100 kHz, so a converter with sampling frequency at least 200 kHz must be used. For measurement was used 16-bit 250 KSPS device and a custom program in LabVIEW was made. It allows setting measuring hardware, data acquisition and calculating power

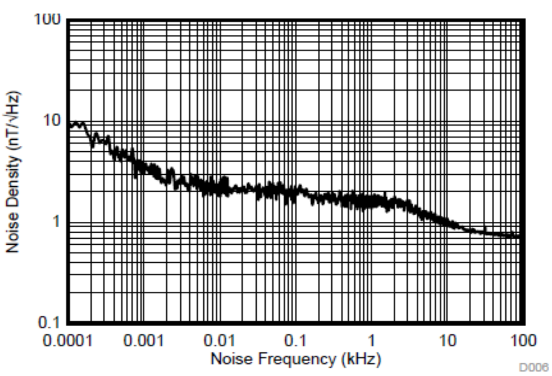

Figure 4: Sensor Noise Density vs Noise Frequency given by producer [2]

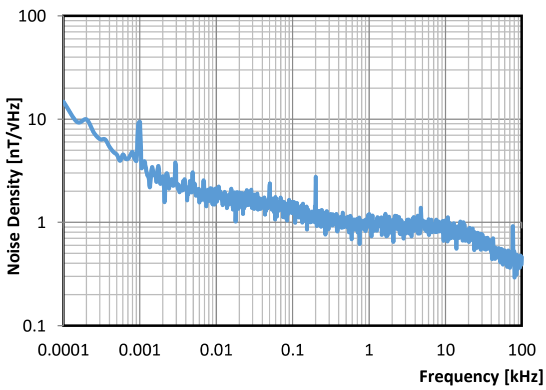

Figure 5: Measured noise density

spectrum density of measured signal. It also repeats the measurement and calculates average from preset number of measurements.

Noise characteristic determined by producer is in range 0.1 Hz to 100 kHz. Length of record must be at least 10 s to fulfil this requirement. For veracity of measurement is necessary to compare the noise of the sensor with noise of the capturing device. Noise of the capturing device must be at least one level lower than noise of the sensor, otherwise the measurement would be distorted and this matter was met.

Output of function calculating power spectrum density is in unit of V^2_{RMS}/Hz and the demanded unit is nT/√Hz. It is necessary to calculate square root measured data and obtain values in VRMS/√Hz and apply sensitivity of the sensor to achieve noise in magnetic domain. By comparison of Figure 4 and Figure 5 can be spotted slightly bigger noise at lowest frequencies and few peaks in measured characteristics which not occur in specification by producer. Producer also states in datasheet noise at frequency 1 kHz as 1.5 nT/√Hz, measured was 1.2 nT/√Hz, and noise in range 0.1 Hz to 10 Hz as 17 nT, measured was 9.2 nT. Both parameters were measured in the same range, even with better results. For calculation of result in specified range of frequencies is necessary to perform numeric integration. The result must have units of nT, hence the measured characteristics in nT/√Hz cannot be integrated. Integration must be performed in units nT2/Hz and then a square root must be calculated.

3.4. NEGATIVE INFLUENCES TO MEASUREMENT

Results of measurement does not compose only of tested input, but measurement is also affected by some parasitic influences and it is important to define rate it import in the result. One of the most common parameter is temperature. Since the producer mentions gain drift ±7 ppm/°C and offset drift ±5 nT/°C, the thermal dependence be ignored. It does not mean big error, because the ambient temperature is stable during the measurements.

4. RESULT

For a selected magnetic field sensor was described a method testing its key parameters like sensitivity, linearity, offset and noise density. All of the parameters were verified with a close tolerance to values specified by producer, the procedure leading to obtain these parameters is applicable and can be repeatedly used for verification of other sensors.

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